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Fire Fuels in RED PINE PLANTATIONS

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by
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LAKE STATES FOREST EXPERIMENT STATION
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FIRE FUELS
in
RED PINE PLANTATIONS

by Loyd LaMois

Lake States Forest Experiment Station[1]

INTRODUCTION

Protecting conifer plantations from fire has become an important part of the fire control job in the Lake States. Since they are valuable investments in forest growth, and generally exposed to high levels of fire risk, the almost 1½ million acres of successful pine plantations in Michigan, Minnesota, and Wisconsin represent a special fire control problem in the area. A steadily increasing rate of planting in the three States, aimed at eventual coverage of the region's 7½ million acres of plantable commercial forest land, moves the problem of future protection into today's fire control planning.

Crowning of Fire is Special Hazard

The fire control problem in pine plantations is centered in the fact that wildfire usually results in their total destruction. This is due to the small size of the trees and the fact that conifers crown readily under conditions that preclude crowning in broadleaf species (fig. 1).

The crowning of fire is of major concern to fire fighters everywhere. Fires that crown are generally the most rapidly spreading and most difficult to control, and they do the most damage. Presuppression measures which would tend to minimize the probability of crowning fire in young pine stands are urgently needed.

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[1] Maintained at St. Paul 1, Minn., by the Forest Service, U. S. Department of Agriculture, in cooperation with the University of Minnesota.

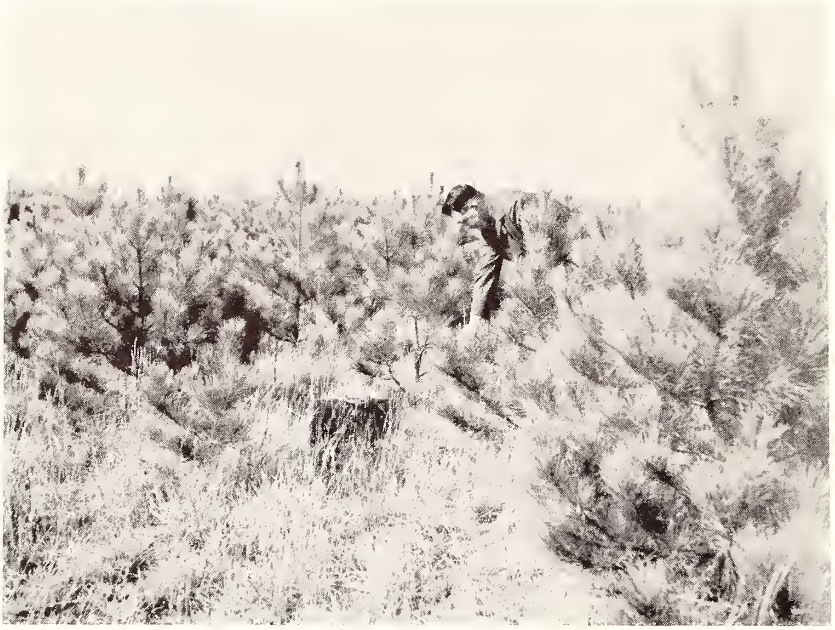

Figure 1.--These small trees would be in danger of "crowning out" if a fire should start in the heavy grass cover.

Ground Fuels are Important

Under extreme fire conditions in the Lake States, involving high wind velocities, fire can be carried for long distances through the crowns. However, under less extreme conditions the running fire depends mainly upon the ground fuels. Short runs through the crowns occur when the surface fire is picked up and swept into the crowns by wind gusts; but most crowning progresses behind the running front of surface fire, the flames flaring up into the live crowns only after thorough drying and heating from the burning fuels below.

This focuses attention upon the fuels on the ground or immediately below the live crowns. These fuels assume special significance where the size and nature of the tree cover convert an ordinary surface fire into a crown fire. For this reason a study of fuels was undertaken in young plantations to provide a better understanding of their relationship to stand condition.

DESCRIPTION OF STUDY

The objectives of the study were: (1) To determine the range of quantities, by weight, of the forest fire fuels in Lake States red pine plantations, exclusive of the live tree crowns themselves, and (2) to determine how the amounts of fuel vary with respect to the spacing and age of the trees and the quality of the plantation site.

While factors such as size, arrangement, moisture content, and distribution of fuels are of paramount importance, the fact remains that for any given type or kind of fuel present, the amounts (or weights) involved are basic to the behavior pattern of the fire and to the problem of crown ignition once fire has started.

This study concerned itself only with the tree spacing, age, and site quality associated with the 75 red pine plantations observed. However, it is recognized that several other factors not considered here affect the amounts of fuel to be found in any one stand. Some of these are: (1) Pre-existing ground cover on the planting site, (2) planting site preparations, (3) presence of mature overstory, and (4) cultural treatment in established stands. Subsequent investigations will be designed to show the influence of these and other factors, including species planted, upon the fuel quantities involved. Red pine was used in this study because it is one of the most commonly planted species in the Lake States.

Fuels

The fuels sampled were the "flash type," i.e., those that, during the fire season in the Lake States, are in an air-dry state and very responsive to current weather conditions. These are: (1) The grass and herbaceous ground cover, (2) the needle litter,[2/] and (3) the dead branches below the live portion of the tree.

Considerable amounts of brush occur in many red pine stands in the Lake States. However, the woody stems are seldom an important fuel in themselves; their main contribution to forest inflammability is the leaf litter they add to the forest floor.

[2/] Needle litter as collected in this study includes that portion of the forest floor described in many soil texts as the L (litter) and F (duff) layers. Raw humus, or the H layer, was excluded in stands where definite layers were distinguishable.

Method of Sampling

Fuel samples were gathered from 102 1/10-acre (1-chain square) plots of varying site quality, plantation age, and stand density. In general, plantations were sampled in areas within each of the three Lake States where red pine had been planted extensively (table 1).

Table 1.--Location of sampled red pine plantations and number of plots by county and State

County	Number of plantations	Number of plots
	MINNESOTA	
Clearwater	2	3
Beltrami	3	5
Cass	3	4
Hubbard	2	3
Total	10	15
	MICHIGAN	
Wexford	19	25
Manistee	1	3
Iosco	8	10
Oscoda	2	3
Roscommon	1	1
Total	31	42
	WISCONSIN	
Oconto	9	11
Langlade	2	5
Forest	1	1
Price	2	3
Bayfield	1	1
Portage	3	4
Wood	3	5
Adams	13	15
Total	34	45

Density was evaluated as a percent of Rudolf's average stocking standard for Lake States plantations.[3] Because the selection of plantations for use in this study was biased in favor of generally successful pure plantings in open sites, poor density in this study corresponds with Rudolf's average stocking curve. Medium and good densities are respectively 1.5 times and 2.0 times his values over the range of ages (fig. 2 on next page).

Site quality was evaluated by assigning a 50-year site index rating adapted from Rudolf's expected height growth for red pine plantations in the Lake States. The site index was based on the average height of the five tallest trees in the sampling plots (fig. 3 on next page). It is recognized that the height growth of very young stands (less than 15 years) often is not a valid estimate of true site quality. However, in this study site index was used more as a scale of actual tree growth rate and less as a measure of soil potential as it is conventionally used.

Age was estimated by whorl counts on two or more trees per plot. Table 2 shows the plot distribution by age, density, and site.

Table 2.--Distribution of sampled stands by age, density, and site

(In number of plots)

	Poor site			Medium site			Good site			
Age group (Yrs)	Poor density	Med. density	Good density	Poor density	Med. density	Good density	Poor density	Med. density	Good density	Total
5-10	2 -	-	-	4	2	4	2	5	3	22
11-15	-	1	2	5	6	3	4	2	11	34
16-20	1	4	2	4	6	1	3	6	2	29
21-25	-	-	-	-	-	-	-	-	-	0
26-30	-	1	1	1	1	2	-	-	-	6
31-35	2	3	2	1	1	1	1	-	-	11
Total	5	9	7	15	16	11	10	13	16	102

3/ See "Literature Reviewed."

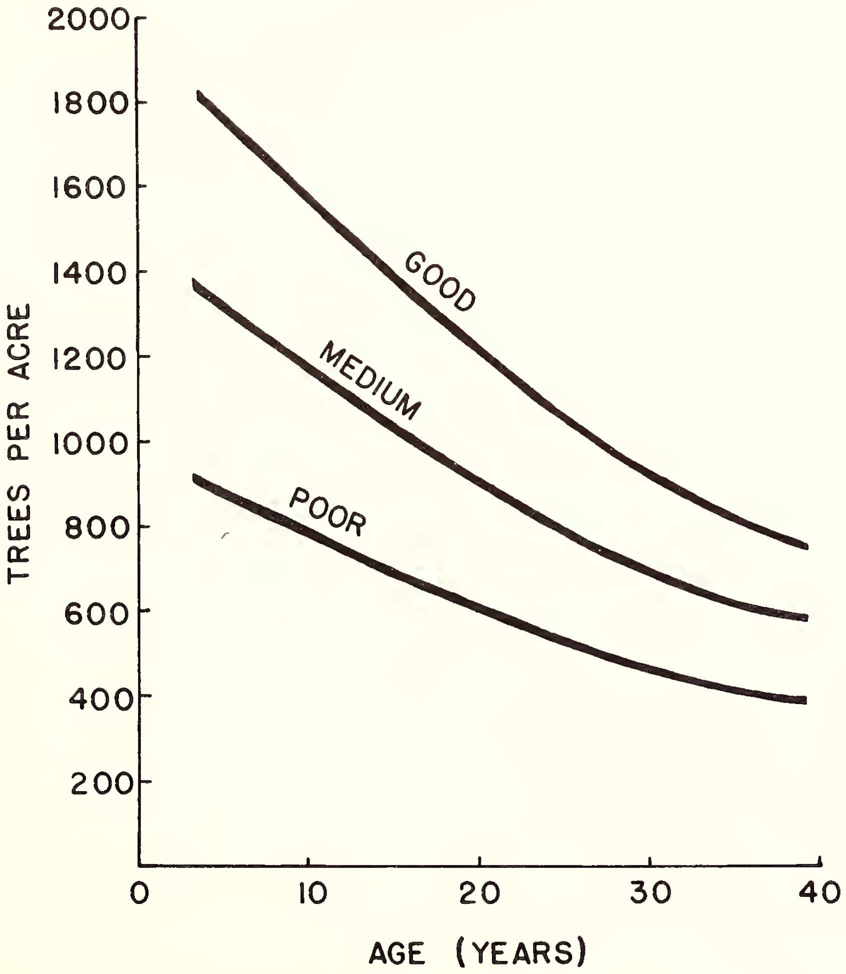

Figure 2.--Density class as defined and used in this study.

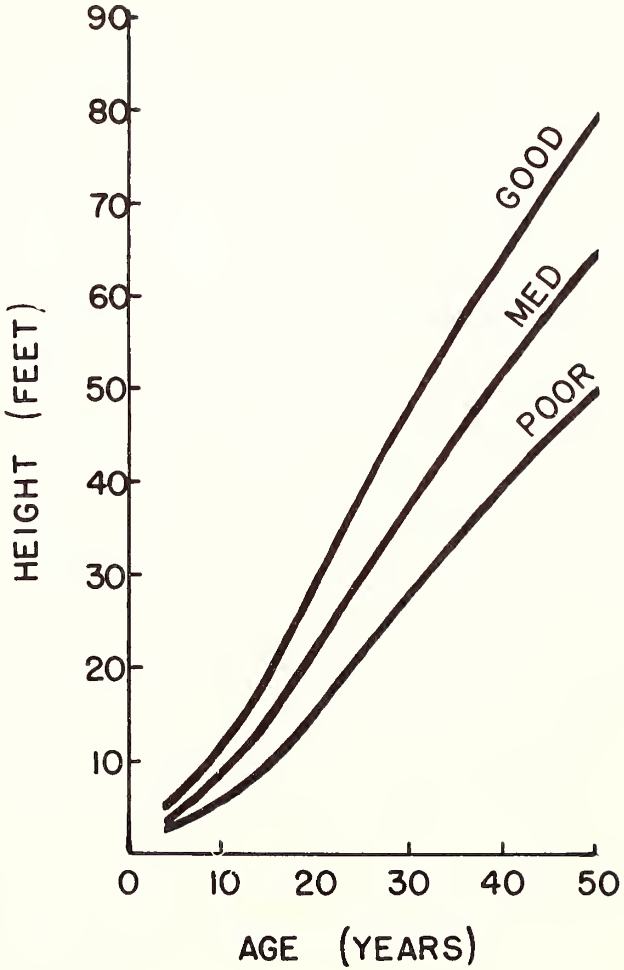

Figure 3.--Site class as defined and used in this study.

Ground cover and needle litter were sampled at 10 points along a straight line extending diagonally from the center tree to the first established corner of the plot. Over the range of spacings encountered, this arrangement provided an unbiased traverse of ground area under tree crowns and between trees.

The grassy and herbaceous vegetation was sampled by clipping at ground level all growth on ten 1-foot squares spaced at 3-foot intervals along this line. Litter was collected at 3-foot intervals along the same laid-out line. Where litter was of sufficient and constant amounts, a circular metal pillbox was used. It was punched down through the litter bed to remove a plug which was scraped free from soil before being emptied into the litter sample sack. Where litter volumes were small, collection was made by hand over the 1-foot square which had been clipped free from grass.

Dead branch weights were obtained by clipping all dead branches to a 7-foot height from the two trees closest to the center of the plot.

All sample material was dried in a forced-draft forage drier[4/] operating at temperatures in excess of 100° F. The collected samples remained in the drier over the weekend and through the first part of the succeeding week during which new collections were being made in the field. This period of time never was less than 120 hours, and often extended over a full week. In work with cereal grains and field crops the forage drier is assumed to be the equivalent of a standard laboratory scale drying oven, and is used in a similar manner--drying until no further loss in weight occurs. The nature of woody forest fuels being dried here, plus the arbitrary drying period of 5 to 7 days, made it desirable to calibrate the forage drier in terms of a standard known value.

For this reason several samples of all three types of fuels were dried for 5 days in the drier, and then brought into the laboratory for moisture-content analysis by the solvent distillation method described by C. C. Buck.[5/]

The indicated moisture content of the fuels by reflux distillation in xylene immediately upon removal from the forage drier varied from less than 0.5 percent for dead wood samples to 1.8 percent for litter and

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[4/] Acknowledgment is made to the Agronomy Department, University of Minnesota, for the use of their forage drier.

[5/] Buck, Charles C. The solvent distillation method for determining the moisture content of forest litter. U. S. Forest Serv., Calif. Forest & Range Expt. Sta., 24 pp., illus. April 26, 1937. (Typescript.)

grass. After a delay of 4 hours at room temperature of about 70° F. and relative humidity of 42 percent, a second set of samples showed I.M.C. (xylene distillation) varying from 1.4 percent for dead wood to 2.6 percent for litter and grass.

No field samples were removed from the drier more than 3 hours previous to weighing during the study. The "dry" weights obtained, therefore, could be converted to a "xylene dry" basis by subtracting from 0.5 percent to 2.5 percent from the indicated "dry" weights.

Analysis of Data

Analysis of data recorded in this study was done by the graphic method of successive approximation. For each of the three types of fuels, recorded fuel weights were first plotted as a function of plantation age. The difference (or ratio) between the actual weight value and the curved approximation for each individual case was plotted as a function of site quality to yield a base for the second approximation. A third, and final, approximation was computed using the curve of differences, or ratio, between individual actual values and second approximation values plotted as a function of stand density.

RESULTS OF STUDY

Grass and Herbs

The amounts of grass and herbaceous fuels found are little affected by planting density, age, or site quality during the first 9 or 10 years. Weights of this fuel type occur up to 4,000 pounds of dry fuel per acre, and are a result of previous history of the planting site and ground preparation at time of planting.

On good growing sites and at good density (more than 1,200 trees per acre) crown closure can take place as early as the ninth year. Within 2 years after crown closure the amounts of living grass and herbaceous vegetation seldom exceed 300 pounds per acre, which is the approximate lower limit for fire-carrying ability.

At less than good density or on less than good sites the pine stand broadly limits the amount of grass fuels through the influence of crown cover. At ages beyond 25 years, grass and herbaceous ground cover have been eliminated as a source of ignition for crown fires within plantations on any site at stocking levels down to 400 trees per acre.

Dry weights of living grass and herbaceous stems were matched approximately at a 1:1 ratio by the weights of dead grass and herb material in the form of litter. Thus, figure 4 (on next page) gives the weights of living ground cover alone and also the total fuel weight of the standing stems combined with the dead material in litter form. The top line in figure 3 defines the upper limit of grass and herb weights per acre found in Lake States plantations on less than good sites or with stocking of less than good density. The bottom line defines the upper limit of fuel weights found in plantations on good sites and of good stocking. Below these maxima the weights of collected fuel vary greatly, the effects of site quality and stand density being almost completely masked by greater influences of local vegetative patterns.

Needle Litter

The development of a graphic analysis of the effect of age, site index, and stand density on needle litter accumulations is shown in figure 5 (on page 11). Final results are given in the series of curves in figure 6 (on page 12).

Needle litter accumulates under a red pine stand at an ever-increasing rate until shortly after closure of the crowns. The accumulation then levels off at values ranging from 11,000 to 16,000 pounds per acre under the maturing stand (fig. 6).

On better sites the peak rate of needle litter deposition occurs at earlier ages than on poorer sites where crown closure is delayed. However, high rates of early litter accumulation level off rapidly as the stand moves into the pole-size timber class. On poorer sites crown closure is not only delayed, but also appears to be a more gradual process. This results in less rapid needle accumulation during crown closure and in less drastic leveling off during postclosure stand development.

Measurable differences in total litter accumulation, resulting from differences in site quality, occur in Lake States red pine plantations well past 30 years old. It is doubtful that such differences exist after the stands reach early maturity (50 to 60 years).

The effect of stand density is similar to, but less than, the effect of site upon needle litter fuels. Reduced density delays crown closure on any one site, but after closure the buildup rate is little affected by the number of trees forming the canopy. Therefore, by ages beyond 25 years the effect of stand density is not important.

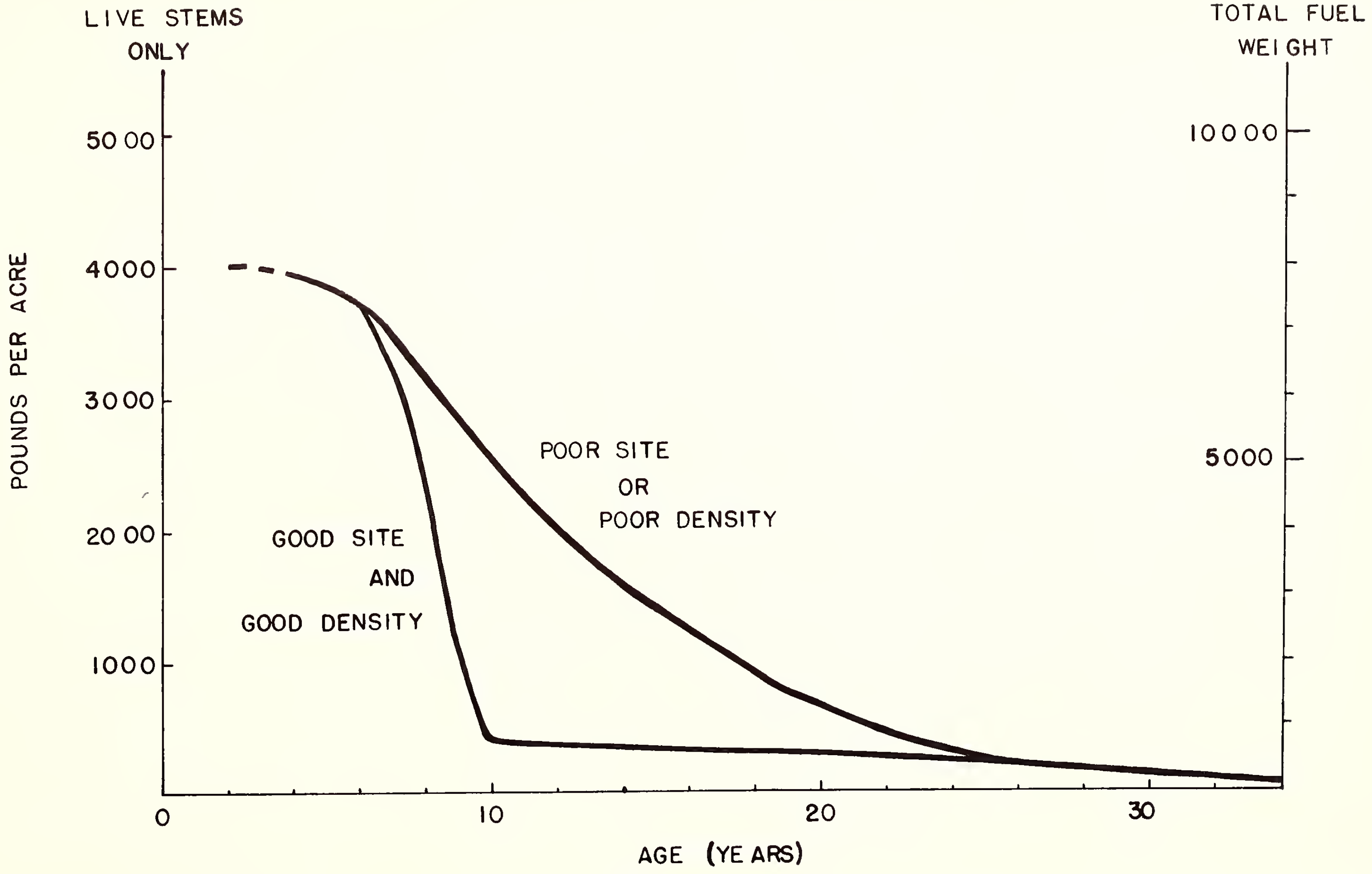

Figure 4.--Maximum amounts of grass and herbaceous ground cover in red pine plantations, Lake States.

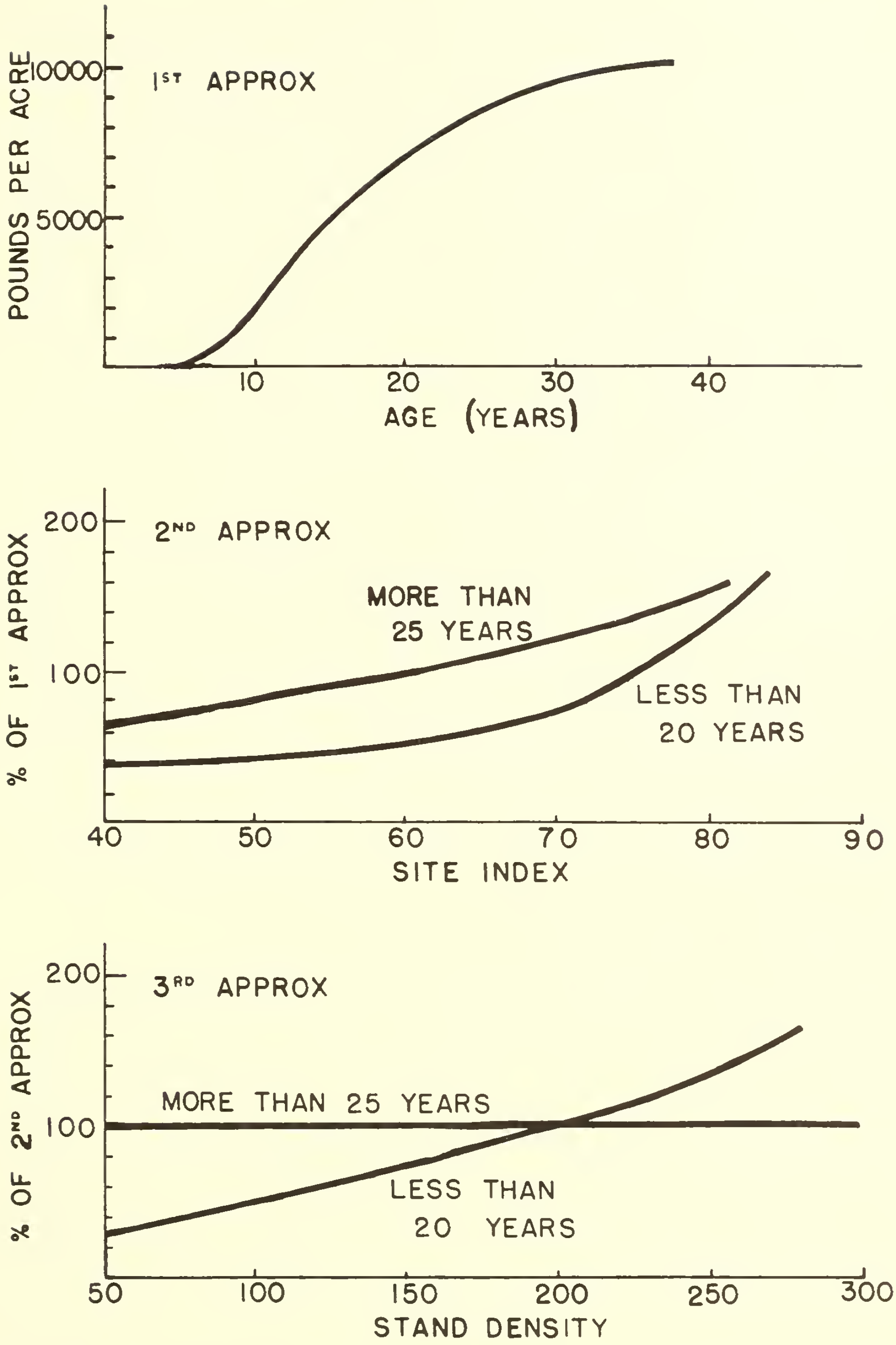

Figure 5.--The development of a graphic analysis of needle litter accumulation under red pine plantations by age (1st approximation), site quality (2d approximation), and stand density (3d approximation); Lake States.

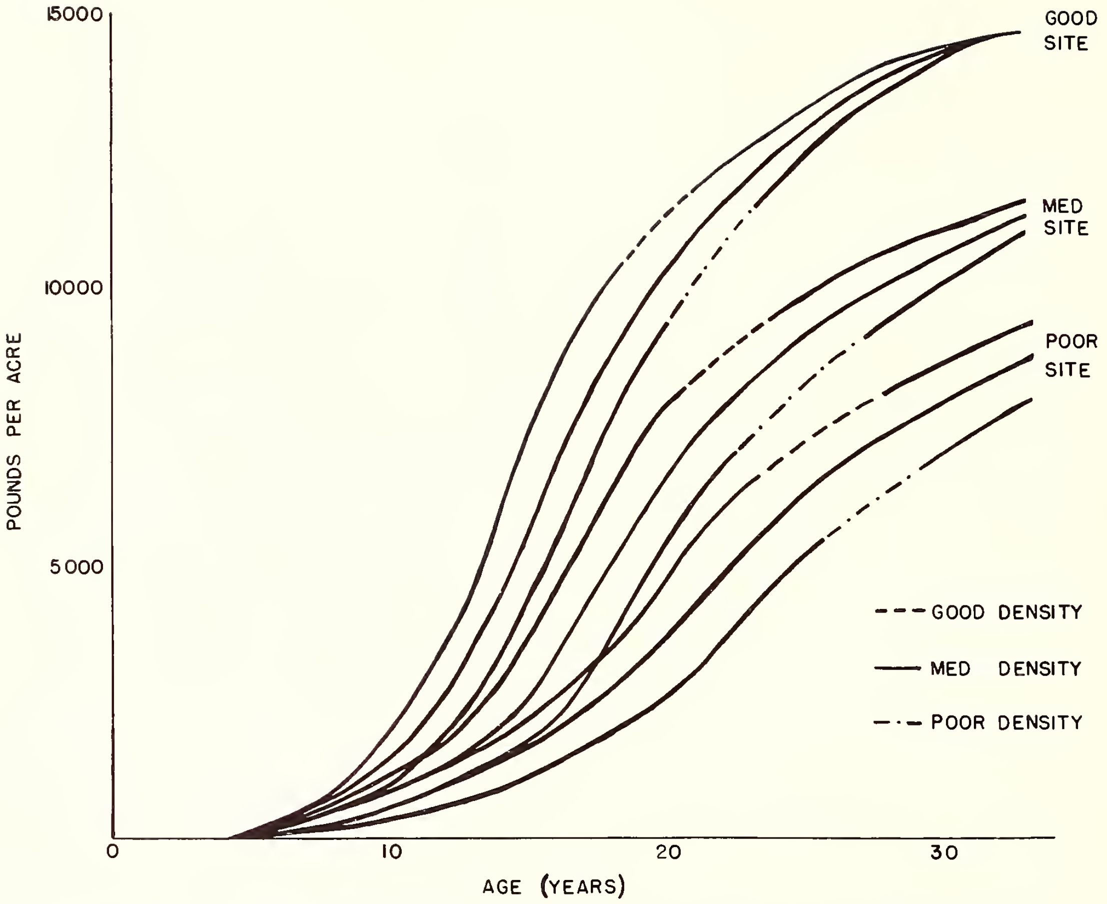

Figure 6.--Needle litter accumulation under red pine plantations by age, site, and density; Lake States.

Until the maximum accumulations have developed, nearly all of the needle material is sensitive to short-term moisture conditions, and is, in every sense, a flash-type fire fuel (fig. 7 on next page). After buildup of a continuous bed of needles to weights in excess of 10,000 pounds per acre, the formation of a duff layer under the top one-half inch of litter changes the character of the bed as a fuel. The lower portion of the needle bed is often matted with fungus mycelia and is normally too wet to burn readily. Although in unusual periods of extended drought this duff layer may dry out so that fire would smoulder in it and carry over to ignite the more flammable surface fuels, it would seldom contribute directly to the crowning of fire. Nevertheless, the top one-half inch of continuous needle bed, consisting of 6,000 to 9,000 pounds of air-dried material per acre, remains a fire fuel that is capable of transferring ground fire to the live crowns under proper conditions.

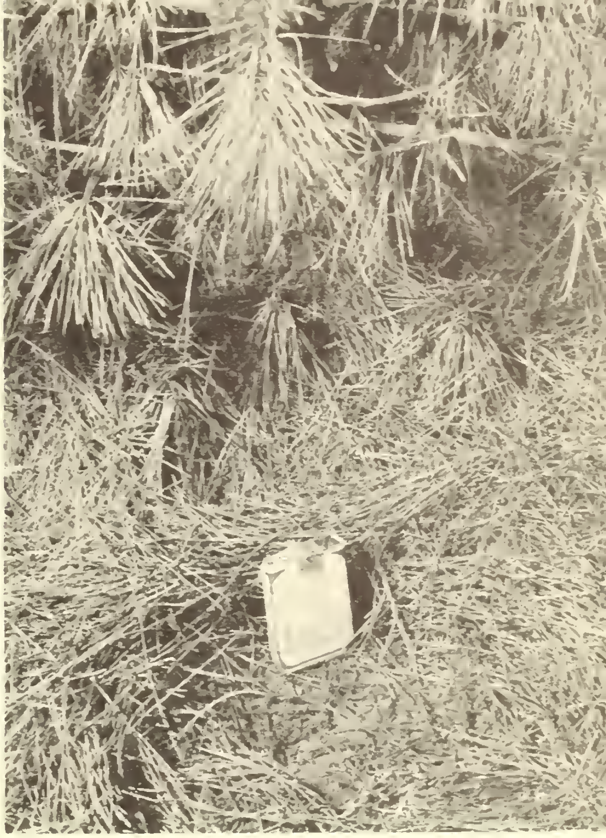

Figure 7.--Heavy accumulations of needle litter at the base of trees that have dead branches extending from the ground upward, afford ideal conditions for crowning of ground fire.

In the plantations examined, plantation furrows tended to have heavier accumulations of needles. Often, also, furrow litter was more loosely packed and seemed to offer more hazardous conditions than did the general pack on level ground.

Kittredge[6] cites several references to annual variation in needle deposition. In some cases variations of as much as 300 percent were reported. Inasmuch as the total accumulation on the ground includes the annual depositions over only a 4- to 5-year period, samples of total accumulations conceivably could vary widely. It is unknown if such variance was restricted to a single stand or if it was evident generally through a region experiencing similar seasonal weather.

Dead Branches

A graphic analysis, similar to that made on needle litter, was developed for the amount of dead branch material in the first 7 feet of the stem (fig. 8 on next page). The final series of curves by age, site, and density is shown in figure 9 (on page 15).

In Lake States red pine plantations, dead branches rarely appear before ages of 11 to 15 years, and then only on good sites and at densities greater than 1,000 trees per acre. On poor-to-medium sites the bottom branches seldom die before 16 to 20 years and then only at densities in excess of 1,200 trees per acre (fig. 9).

Weights of dead branch material in the first 7 feet of bole build up to maximum values rapidly after the first or lowest whorl of branches dies. Maximum values of over 5,000 pounds per acre occur in Lake

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[6] See "Literature Reviewed."

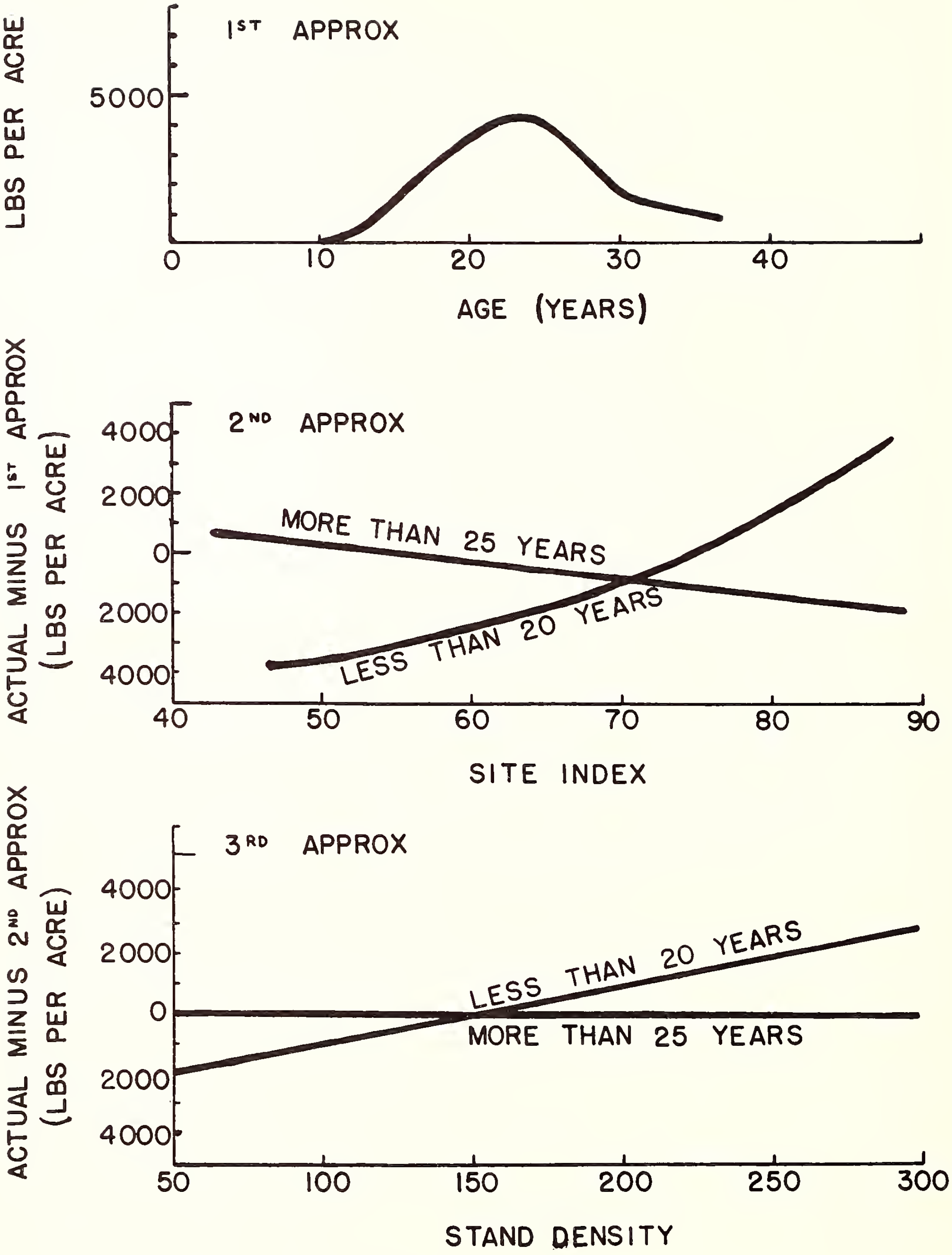

Figure 8.--The development of a graphic analysis of dead branch material in first 7 feet of stem in red pine plantations by age (1st approximation), site index (2d approximation), and stand density (3d approximation); Lake States.

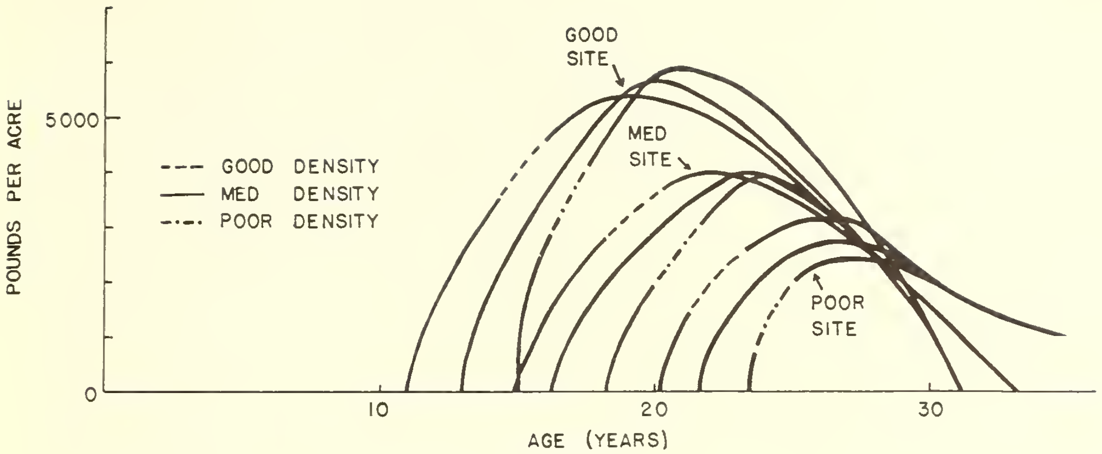

Figure 9.--Dead branch material in first 7 feet of stem in red pine plantations by age, site, and density; Lake States.

States plantations on good sites within 6 to 8 years after the first branches start to die. At densities of more than 1,700 trees per acre these weights are accounted for in the first 5 feet of bole, and can occur at ages as early as 14 to 16 years on good sites.

After this maximum has been reached, there is a falling off of weight values as the dead branches are broken up and finally reduced to bare stubs along the lower portions of the bole (fig. 10 on next page). This reduction phase is generally in progress on all but the poorest sites after age 25. On good sites, the red pine trees are fairly free of fire-hazardous branch material up to well above 15 feet at 30 years of age. On poor-to-medium sites, reduction in weight of dead material has taken place up to 7 feet at 30 years, and thereafter only in unusual cases is dead branch material sufficient to contribute to the crowning of a surface fire.

Good site quality hastens the appearance of dead branches and speeds the dying of branches in the first 7 feet of stem. Greater maximum weights of dead and dying branches occur in rapidly growing stands than on poorer sites where death of higher branches is delayed until the lowest (and first) dead branches have started to break up and slough off. After the lower parts of the stems have started to clean themselves of dead branches, the effect of site is reversed--greater weights of dead wood are found on the poorer sites.

Again, as in the case of needle litter, the effect of stand density is similar to that of site quality. Close spacing of trees hastens the first appearance and peak volume occurrence of dead branches. On good sites, stands of poor density contain greater weights of dead branch wood because the branches are larger and better developed by the time

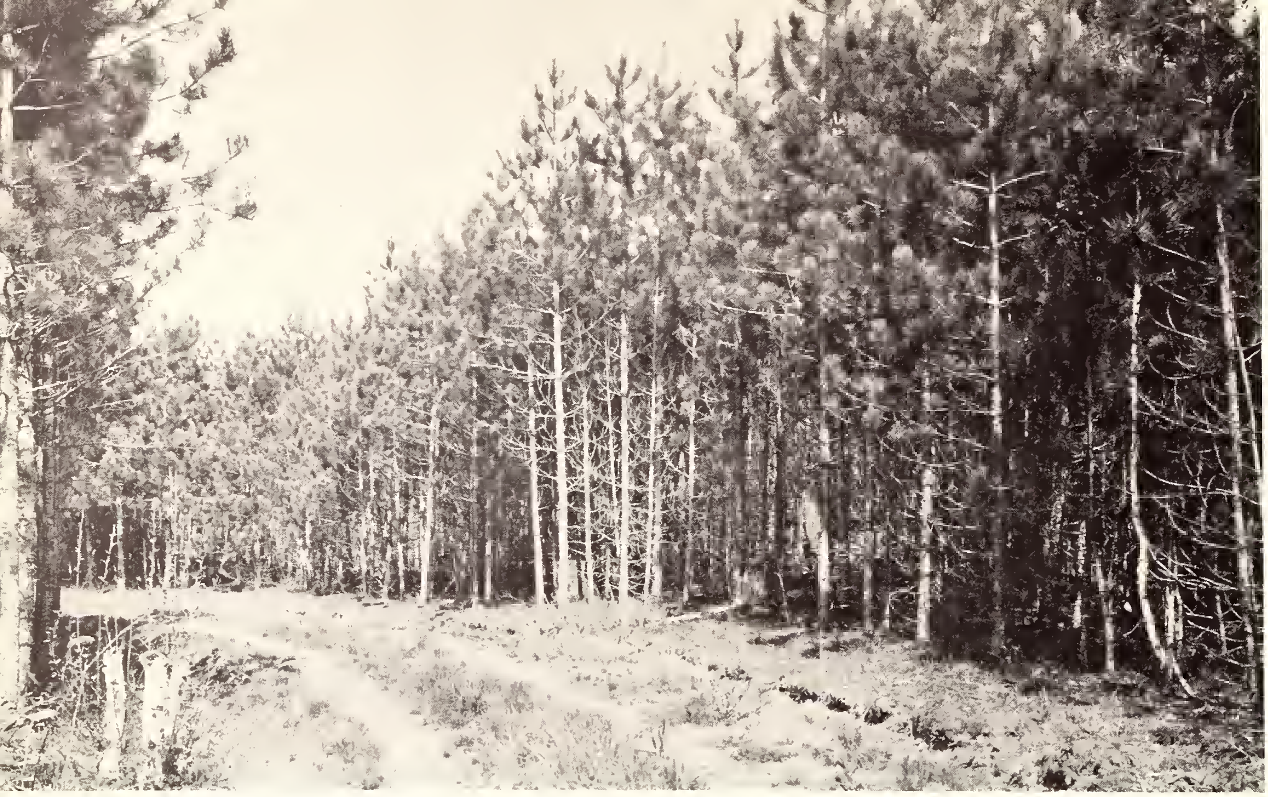

Figure 10.--Unpruned trees have started to clear themselves of dead branches at the age of 20 years. Very close spacing and excellent site quality will leave stand free from fire-hazardous dead branches before 30 years of age.

crown closure brings about their mortality. On poor sites, the delay of maximum weights of dead branch material because of lesser densities resulted in lower peak values through reduction of numbers of dead branches existing at any one time. The effect of stand density is secondary to that of site during the time when the tree boles are being cleaned of dead branches, and becomes unmeasurable before 30 years of age.

Because of early death of lower limbs, the small dead branches in the stands of fast-growing, closely grown trees are more inflammable than in stands where poor site quality or open spacing has delayed death of branches until most of the weight is in limbwood too large to burn readily.

Artificial pruning, of course, greatly reduces the likelihood of fire crowning in any stand (fig. 11 on next page).

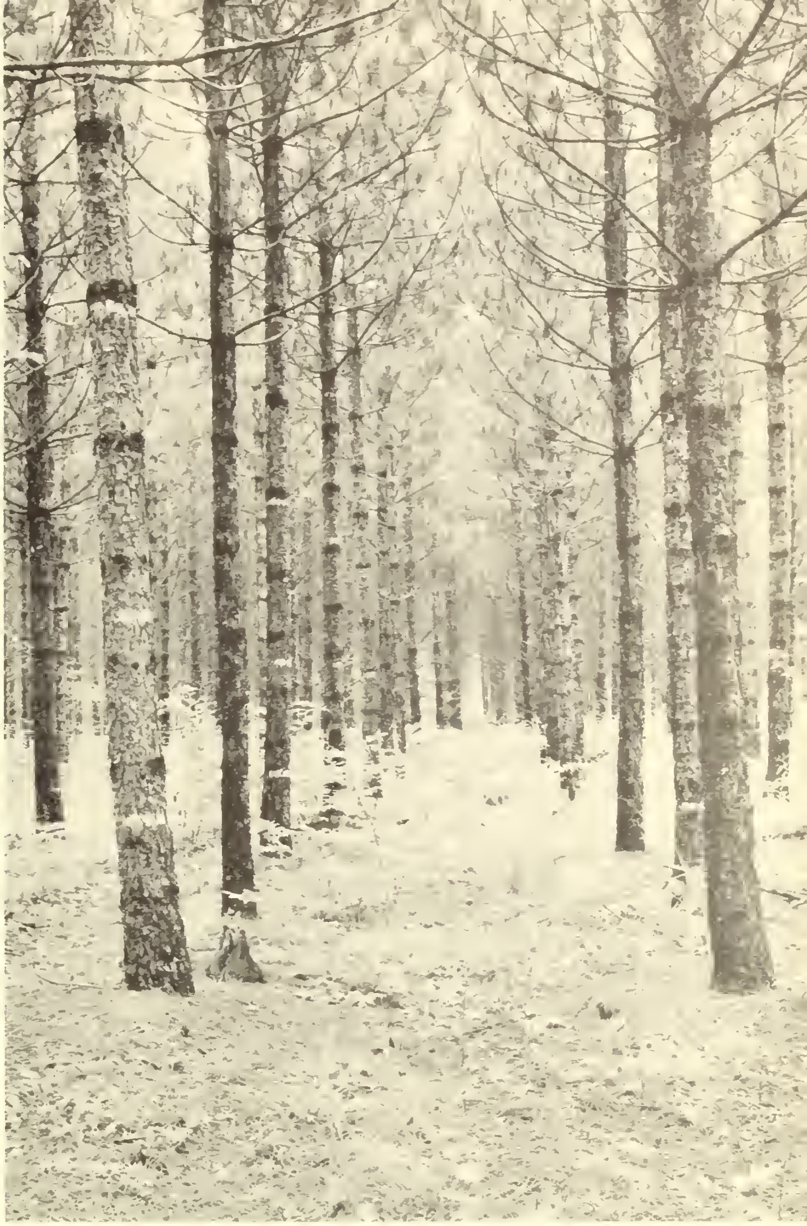

Figure 11.--This stand was pruned at age 20 years. Live crowns are safely above heavy accumulation of needle litter below.

CONCLUSIONS

The intensity of wildfire and the probability of its spreading subsequently to the live crowns of the tree canopy are dependent largely upon the amounts of fuels upon which it feeds. This study shows that stand density and site quality influence the amount of fuels in red pine plantations.

Good sites and close spacing of trees both promote rapid buildup of fuels in the form of litter and dead branches. On the other hand both shorten the period when fire is likely to crown. Early crown closure also brings about early suppression of hazardous grass fuels. Poor site quality and more open spacing of trees delay the buildup of fuels necessary for high intensity fire; but both drastically stretch out the period of time over which live tree crowns are in danger of ignition from a running ground fire.

While the general relationships developed from analysis of available data are well defined, only a rough approximation of fuel weights to be found in a plantation of given age, spacing, and growth rate can be made with confidence. More precise estimates, or predictions, of fuel hazard to be encountered (other than direct measurement of specific situations) undoubtedly could be developed using height alone as a factor which combines the influence of age with that of site quality.

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